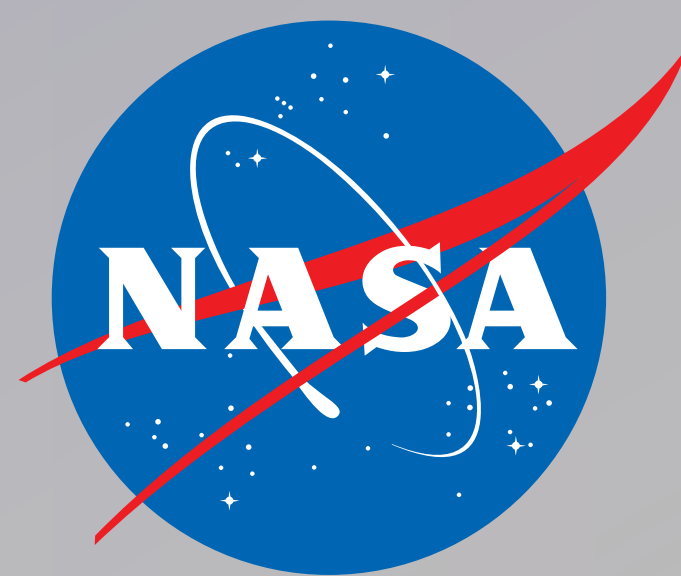


800 °C Silicon Carbide (SiC) Pressure Sensors for Engine Ground Testing

National Aeronautics and
Space Administration

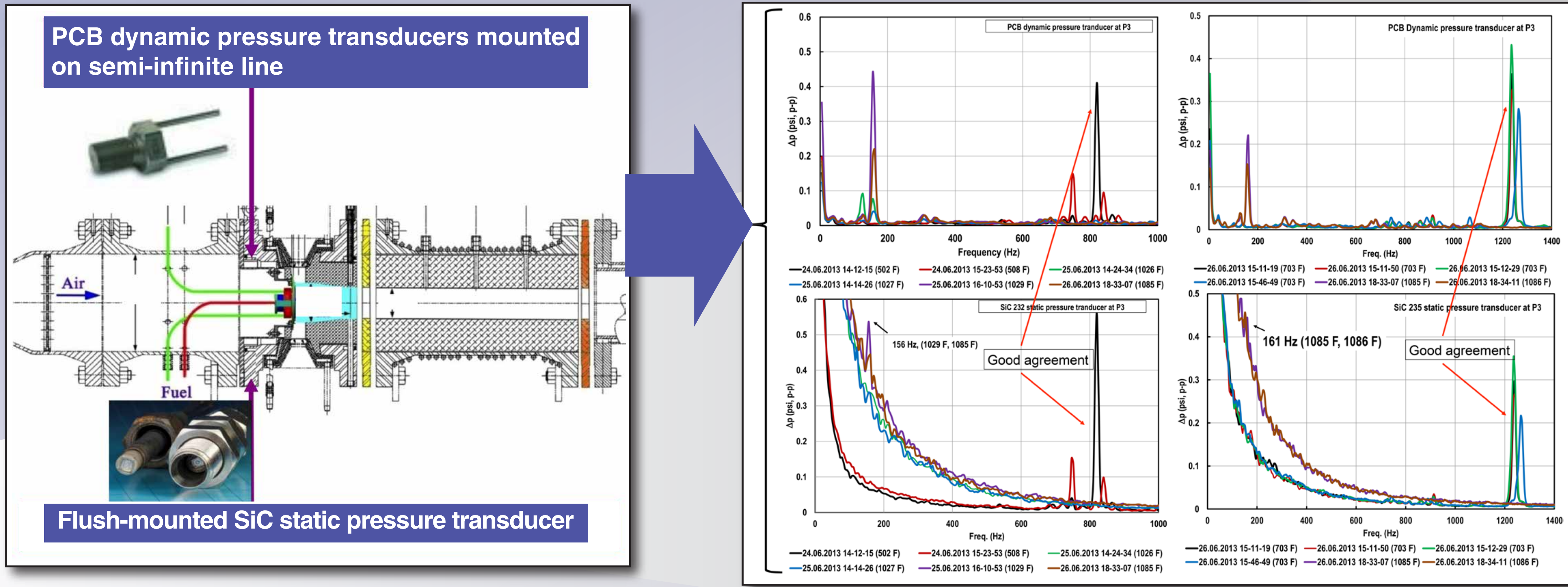


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ABSTRACT
MEMS-based 4H-SiC piezoresistive pressure sensors have been demonstrated at 800 °C, leading to the discovery of strain sensitivity recovery with increasing temperatures above 400 °C, eventually achieving up to, or near, 100% recovery of the room temperature values at 800 °C. This result will allow the insertion of highly sensitive pressure sensors closer to jet, rocket, and hypersonic engine combustion chambers to improve the quantification accuracy of combustor dynamics and performance and increase safety margin. Also, by operating at higher temperature and locating closer to the combustion chamber, reduction of the length (weight) of pressure tubes that are currently used will be achieved. This will result in reduced cost/lb to access space.

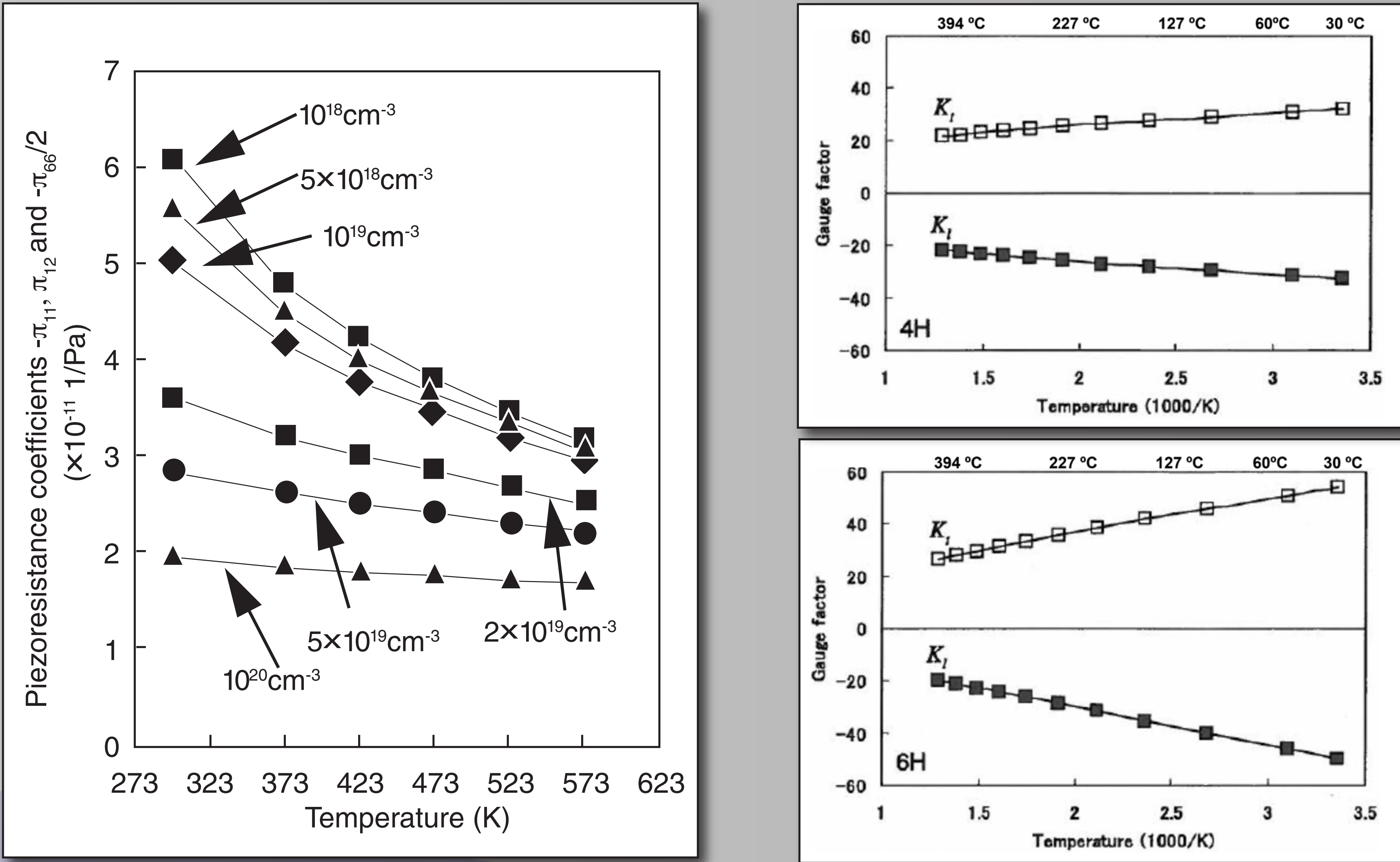
MOTIVATION
Lower emissions (LE) jet-engines are critically dependent on lean-burning (LB) operation. LB/LE combustors are susceptible to thermoacoustic instabilities, producing large pressure oscillations that can reduce component life and potentially cause engine failure. Existing instability prediction models have high uncertainties. Hence, robust pressure sensors are needed for accurate model validation. Conventional sensors placed at a distance from the test article limits frequency bandwidth; water cooling adds “vortex noise” to corrupt signal. Sensors are needed to perform at >500 °C.

COMBUSTOR RIG TESTS AT NASA GLENN RESEARCH CENTER



NOTE
The uncooled SiC pressure sensor is a static sensor that is not optimized for dynamic sensing. However, reduced data from experiments in NASA Glenn CE5 combustor facility compared well against reduced data from water-cooled PCB dynamic sensor. The SiC pressure sensor was exposed to 550 °C flow field while the PCB dynamic sensors were located several inches away to prevent damage. Low frequency noise (<500 Hz) suppressed the SiC sensor output at high temperature, since sensor was not optimized for low frequency sensing at high temperature. Efforts underway to develop SiC dynamic pressure sensors with higher sensitivity to increase signal to noise ratio.

LIMIT OF CURRENT THEORETICAL PREDICTIONS AND EXPERIMENTAL RESULTS



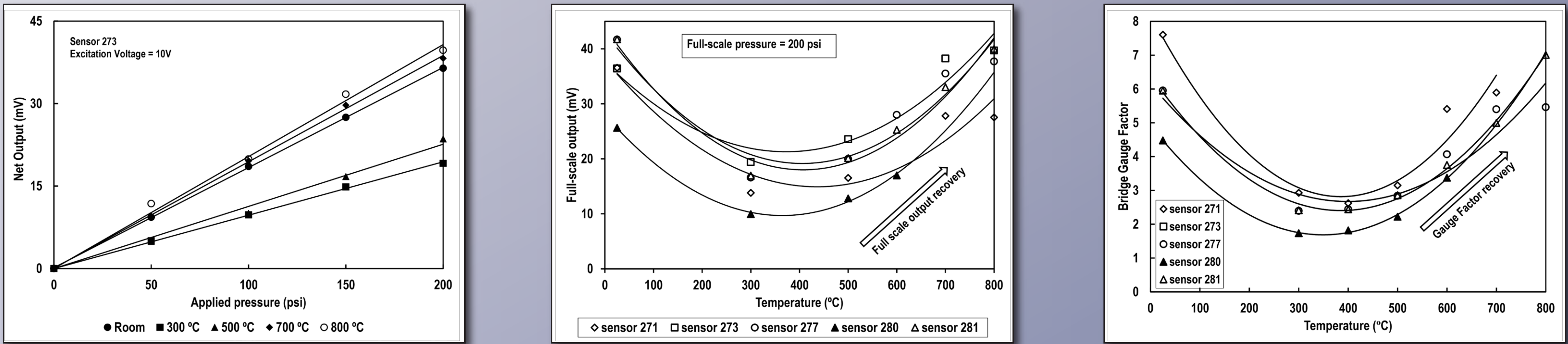
Toriyama, T., and Sugiyama, S., 12th International Conference on Solid State Sensors, Actuators, and Microsystems, Boston, vol.1, Page(s): 758 – 761 (2003).

Theoretical calculation projects to lower values with increasing temperature.

K. Nakamura et al., Jap. Jnl. Appl. Phys. (50), 06GE05. 2011.

Decrease in gauge factors with increasing temperature projects even lower values beyond 500 °C.

TESTING OF SiC PRESSURE SENSORS UP TO 800 °C AT NASA GLENN RESEARCH CENTER

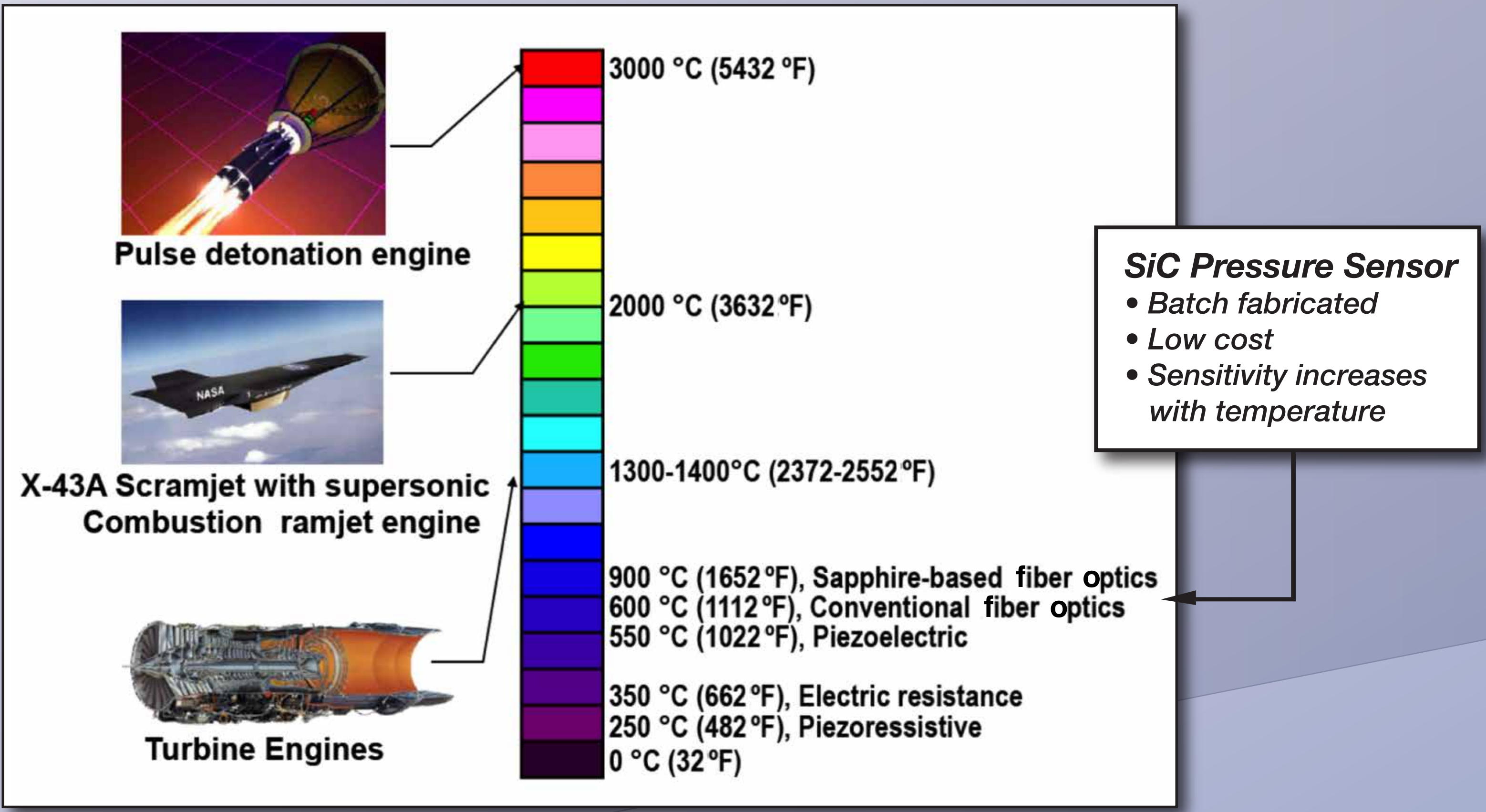


Net output versus temperature shows increase output at 800 °C.

Full-scale (200 psi) output versus temperature shows increasing output from 400 °C.

Bridge Gauge Factor versus temperature.

IMPACT OF FINDING ON TEST PROGRAMS



CONCLUSION
The demonstration of 4H-SiC piezoresistive pressure sensors at 800 °C is reported for the first time, to the best of our knowledge, [Okojie et al., IEEE Electron Device Letters, vol. 36, issue 2, 2015]. The characteristic sensitivity recovery beyond 400 °C reached values that are nearly equal to the room temperature values at 800 °C. It offers the promise of delivering the room-temperature-level sensitivity at the highest operating temperature, thereby making it possible to insert the sensors further into higher temperature sections of the test article without the need for cooling. The mechanism responsible for this phenomenon and the hypotheses proposed are being investigated.

SPONSOR
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